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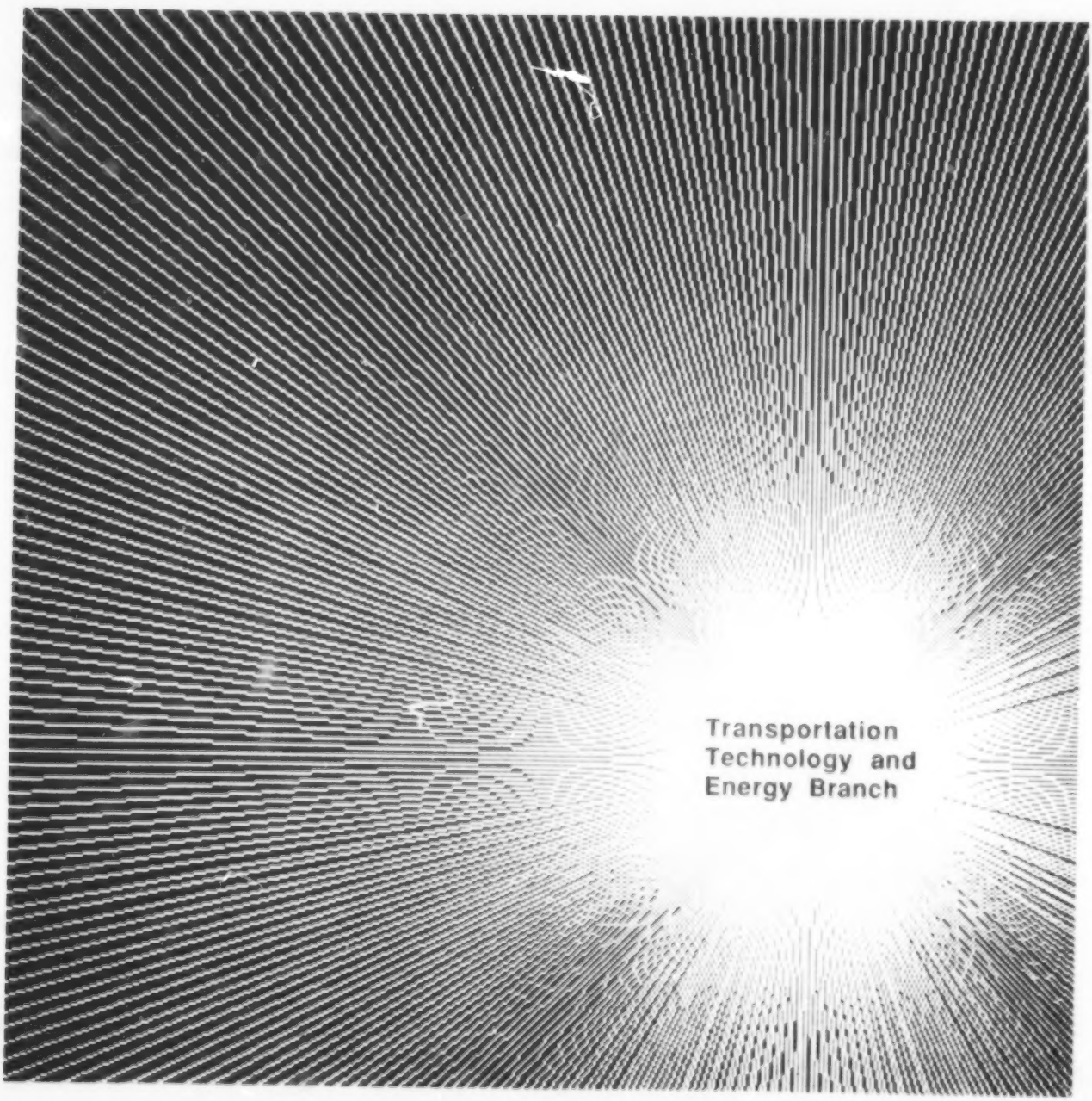

The Development of Natural Gas Buses in Ontario

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EXECUTIVE SUMMARY

Early in 1980, the province of Ontario initiated a conservation and oil substitution program with the objective of reducing the consumption of oil. To achieve this objective in the transportation sector, fiscal support was given to the private sector, and a combination marketing and technology development program was initiated. This submission primarily addresses the transportation technology development program in the area of natural gas vehicles.

The technology development program had three components: research, development, and demonstrations. This program resulted in a series of developments and demonstrations in light- and heavy-duty vehicles and showed the technical feasibility of using alternative fuels, such as propane and natural gas, in the transportation sector. One of the outcomes of this program was the development and demonstration of natural gas powered buses. These buses were developed for environmental, health, energy security, and economic reasons. The development program was initiated by the demonstration of retro-fitted natural gas buses in Hamilton and expanded in 1988 to develop and demonstrate 50 natural gas powered buses. The buses will be demonstrated in Toronto, Hamilton, and Mississauga and are expected to go into service in the latter half of 1990.

Many of the programs were conducted in cooperation with the Canadian federal government, the Ontario provincial government, and the private sector. The cooperation and common objectives of the two levels of government and the private sector provided the impetus for the smooth launching of these programs.

1/ INTRODUCTION

Ontario is one of Canada's ten provinces and has a population of 9.2 million. There are 5.2 million cars/light-duty vans and 0.24 million heavy commercial trucks registered in Ontario. They collectively consume 270 000 barrels of gasoline and 70 000 barrels of diesel fuel daily. Like all highly integrated and industrialized societies, Ontario relies heavily on its transportation sector to move its people and goods on time. When the energy shocks of 1973 and 1979 hit, Ontario's motorists and transportation sector were affected, as were other motorists and transportation sectors throughout the western world. They faced the double problem of uncertainty of price and long-term supply.

Canada's oil is produced in the western provinces and is distributed by pipeline within Canada as far east as Quebec. While the majority of the oil is used domestically, some is exported to the U.S. To minimize transportation costs, oil for eastern Canada is imported from offshore countries. In the late '70s, imports and exports were approximately in balance. While Canada was self-sufficient in its petroleum needs throughout the '70s, the long-term projections developed in the late '70s indicated that a shortfall would develop in the late '80s and early '90s. To make up the shortfall, two options were available: either oil imports could be increased or oil consumption could be decreased. In Ontario, the decision was taken to actively pursue a program of reducing the consumption of oil.

Beginning in 1977, the Ministry of Transportation of Ontario (MTO) undertook a series of studies to determine the impact of a wide variety of measures on the consumption of oil. The studies investigated conservation techniques, the use of oil substitution, and the effects of taxation. The conservation studies considered such factors as the effects of speed restrictions, driving techniques, proper vehicle maintenance, use of smaller vehicles, etc. The oil substitution studies investigated the use of alternative transportation fuels such as propane, natural gas, methanol, ethanol, alcohol blends, hydrogen, electricity, ammonia, and vegetable oils. The taxation studies looked at the effects of taxation on such items as gasoline and diesel fuel, big cars, and air conditioning.

When the oil crisis of 1979 arrived, Ontario had a reasonable understanding of what could be accomplished by using the dual approach of conservation and oil substitution in the transportation sector. Because of the seriousness of the oil crisis and its potential impact on the industrial base and the transportation sector of the province, Ontario felt that it should introduce programs specifically targetted at various sectors, i.e., housing, transportation, industry, etc., to reduce the consumption of oil. Each of the programs developed specific plans and targets to achieve its goal.

For the transportation sector, the Ministry of Energy and the Ministry of Transportation jointly introduced the Transportation Energy Management Program (TEMP) in 1979 to promote the reduction of the consumption of oil. One of the objectives of the TEMP program was to achieve a 2% substitution by 1985 and 10% by 1995 of petroleum products by alternative fuels in road transportation. While reducing oil consumption was the primary objective, the environmental benefits resulting from the use of alternative fuels and conservation practices were additional incentives.

Interestingly, it was the potential environmental benefits resulting from the use of alternative fuels that convinced Ontario to maintain its energy program throughout the mid '80s as the energy crisis faded. As we enter the '90s, the need to protect and preserve our environment is becoming one of the main issues confronting Canada and the world. The issue of sustainable development, of which global warming is an element, has been thrust upon the world as a new challenge to address. Since global warming is closely associated with the production of CO_2, many of the programs in conservation and oil substitution undertaken in Ontario to address the energy crisis are equally applicable today to address global warming.

As mentioned above, TEMP was to achieve its objectives by using the dual approach of conservation and oil substitution. This paper will describe the oil substitution portion of the program, and will focus on the research, development, and demonstrations conducted with natural gas in both light- and heavy-duty vehicles.

2/ ALTERNATIVE FUELS TECHNOLOGY DEVELOPMENT PROGRAM

When Ontario's alternative fuel program began in the late '70s, there were many questions regarding the use of alternative fuels in transportation. The alcohols had questions of materials compatibility, cold weather startability, and costs associated with them. With natural gas, the questions related to power loss, vehicle range, and the capital cost of compression equipment. With propane, the questions related to the quality of the conversions and the quality of the conversion equipment. Because of these and many other questions related to the application of alternative fuels, it was proposed that an alternative fuel technology development program should be initiated.

Consequently, the alternative fuels technology development program was initiated to address three needs:

1/ Provide support to a marketing program.
2/ Provide policy input to the government if required.
3/ Prepare Ontario for the possible introduction of alternative fuels.

To address these needs, the alternative fuels technology development program adopted the following objective:

- Prepare Ontario for the possible introduction of alternative fuels by conducting a program of research, development, and demonstrations.

The strategies to be followed to meet this objective were:

Research
- Conduct research to evaluate each alternative fuel.

Technology Development
- Develop new technologies to utilize alternative fuels.

Technology Demonstrations
- Initiate technology demonstrations to promote new applications and to obtain in-service evaluations.

The alternative fuel technology development program that was conducted in natural gas in Ontario from 1979 to the present is described below.

3/ NATURAL GAS IN LIGHT-DUTY VEHICLES

In Ontario, propane was the first alternative fuel introduced into the transportation sector in 1980. The introduction of natural gas for vehicles followed propane by two years. The main reason for the delay was that there was no infrastructure in place to supply natural gas to the transportation sector. Once the propane program was launched, it was decided that the most effective way to launch a natural gas program was to initiate demonstrations with the natural gas utilities in their own fleets. This would provide the utilities with the expertise and information required to market the product.

Since the utilities had little experience with the use of natural gas in vehicles and had no information on the market potential, it took time to convince them of the merits of undertaking the demonstrations. Two demonstrations were carried out with 25 vehicles in each fleet. One fleet used the utility's vehicles exclusively and a private compressor station on the utility's property. The other demonstration used a compressor station, which was on the utility's property and was accessible to public vehicles. This demonstration used both private and public vehicles. Using information

gained in these demonstrations, the utilities initiated active marketing programs. Today there are 8 000 natural gas vehicles in Ontario and 25 000 in Canada. These demonstrations showed that one of the inconveniences of using natural gas as a transportation fuel is its low energy density. At a pressure of 3000 psi (204 bar), an equivalent quantity of natural gas energy occupies four times the volume of gasoline. This characteristic has a ripple effect. Heavy tanks, either steel, fibre reinforced aluminum, or primary composite, are required to store the fuel. The extra weight has an impact on fuel economy. In volume restricted vehicles, such as cars, the range is typically cut in half and extra trips to the filling station are required. On the filling station side, the need to compress the gas to 3000 psi (204 bar) results in costly compressors.

To address the need to compress the natural gas to 3000 psi (204 bar) and the associated tank weight issue, a research project to investigate the use of low-pressure storage systems was launched by Ontario and Consumers Gas. This project was initiated because it was known that carbon could adsorb methane, the primary constituent of natural gas. The storage pressure of natural gas is reduced in the presence of charcoal because the adsorption of methane onto the surface of the micro-pores in charcoal essentially removes the molecule from the free gaseous state. To maximize the weight of natural gas stored, a charcoal that maximizes the surface area, i.e., the number of micro-pores, for a given volume of charcoal is required. This project resulted in the development of a composite type of engineered charcoal, which is capable of storing at 500 psi (34 bar) a weight of natural gas equal to that stored at 2000 psi (136 bar) in a conventional cylinder of equal volume. While it was determined that natural gas could be stored at reduced pressures in the presence of charcoal, it was also determined that the weight of the charcoal offset the weight saving in the tank [1].

Tests have shown that the effectiveness of the charcoal diminishes as the pressure increases beyond 500 psi (34 bar). When the pressure reaches 500 psi (34 bar), most of the micro-pores are saturated. Any further addition of natural gas goes primarily into the gaseous state and the pressure rises rapidly without significant addition of natural gas. To overcome this phenomenon, an adsorbent material with more micro-pores or a higher surface area to volume ratio is required. A program to develop such materials is being undertaken by the private sector.

When natural gas entered the market, a large number of vehicles were converted to dual-fuel operation. This permitted the vehicles to operate on either gasoline or natural gas. To assess the impact of the conversion equipment on emissions and fuel economy of a baseline gasoline vehicle, a 1981 Ford F-150 pickup truck was converted and tested on a chassis dynamometer. The baseline vehicle was tested on

gasoline before conversion. It was then modified and re-tested on gasoline and natural gas. The results obtained with one of the conversion kits are given below [2,3,4].

	Baseline Gasoline	Converted Vehicle Gasoline	Converted Vehicle Natural Gas
Fuel Economy (L/100 km)	13.49	13.97	13.22*
Hydrocarbons (g/mi)	0.36	0.40	1.51
Carbon Monoxide (g/mi)	2.18	2.55	0.27
Nitrogen Oxides (g/mi)	2.13	2.23	1.24

* Natural gas converted to an equivalent energy volume of gasoline

On this vehicle, reductions in carbon monoxide and nitrogen oxides were obtained while operating on natural gas. However, the hydrocarbon emissions increased above those produced while operating on gasoline. While the natural gas vehicle emitted more hydrocarbons, they are primarily composed of non-reactive methane. Some jurisdictions do not include methane in their emission standards because methane does not react with NO_x to form ozone and smog. Consequently, the overall emissions of the above natural gas vehicle would be considered better than the gasoline vehicle in some jurisdictions.

Since the tests were conducted, stricter emission standards were imposed in Canada in 1988 and it is being proposed that increasingly stricter standards come into effect in 1994. The current and proposed standards are given below. The proposed standard is very similar to the standard proposed for California.

	1981	Current	Proposed 1994
Hydrocarbons (g/mi)	2.0	0.41	0.32*
Carbon Monoxide (g/mi)	25.0	3.40	3.40
Nitrogen Oxides (g/mi)	3.1	1.00	0.40

* Equivalent to 0.25 g/mi non-methane hydrocarbon standard

It was believed that the operation of a vehicle on alternative fuels would automatically result in reduced emission levels. While this was true in the '70s, the emission standards imposed on gasoline powered vehicles have been gradually made more stringent with time. To meet the stricter standards, gasoline fuel metering systems have been designed to accurately meter the fuel to the engine and a three-way

catalyst has been added to treat the engine exhaust. Today, the same fuel metering accuracy has to be applied to alternative fuelled vehicles to meet the current and proposed standards. The development of such a system is being undertaken at Ortech International and is sponsored by a consortium coordinated by the Canadian Gas Association.

4/ GASEOUS FUELS FOR HEAVY-DUTY VEHICLES

Once the programs to use propane and natural gas in light-duty vehicles had been established, the technology development program began to focus on the use of these fuels in heavy-duty vehicles. While it was straightforward to convert a spark-ignited engine to utilize an alternative fuel, such was not the case with diesel engines. Engines that use propane and natural gas require an ignition source. However, diesel engines do not require an ignition system because of the inherent ignition properties of the fuel. Consequently, a system to provide an ignition source and a fuel metering system had to be developed for the diesel engine. In addition, new control systems had to be developed to control engine speed.

The study of the use of gaseous fuels in heavy-duty vehicles was initiated as a result of concern for the environment and the long-term quality, supply, and cost of diesel fuel. Both propane and natural gas appeared to be viable alternatives to diesel fuel in the transit bus market. These two fuels had inherent advantages in the areas of cost, environment, and security of supply [5]. To determine whether these advantages could be realized, a program to develop and demonstrate engines that could utilize these fuels was launched.

4.1/ Natural Gas for Transit Buses

In the early '80s, it was anticipated that the demand for transit service would increase and put further strain on oil supplies. In order to expand the available fuel options to transit systems, it was decided to convert a small fleet of buses to demonstrate the use of propane and natural gas. Because little information was available on the conversion of bus diesel engines to gaseous fuels, it was agreed that the conversion would have to be undertaken directly by an engine manufacturing company.

The demonstration of propane was undertaken in Ottawa in 1983 in a cooperative program between Energy Mines and Resources Canada, the Ontario Ministry of Transportation, the Ontario Ministry of Energy, and Ottawa-Carleton Regional Transit Commission (OC Transpo). A report on this demonstration is available [6].

A demonstration, similar to the propane one, was undertaken with natural gas in 1985. This demonstration was run in Hamilton, and was a cooperative effort between the federal and provincial governments, the bus operator, Hamilton Street Railway (HSR), and the local gas utility, Union Gas. The objective of this demonstration was to evaluate the use of natural gas in transit from an economic, operational, and environmental perspective. The environmental objective, initially, was to reduce the visible smoke and noise.

For this demonstration, six GM buses were converted to natural gas using Dereco/Iveco engines. The engines were rated for 170 HP and were similar to the propane engines except that the compression ratio was 12:1 and the fuel metering system was modified for natural gas. The buses were equipped with seven fibre-reinforced aluminum cylinders, each with a water capacity of 128 litres. This was sufficient to give the buses an estimated range of 250 – 350 km with the cylinders filled to 3000 psi (204 bar).

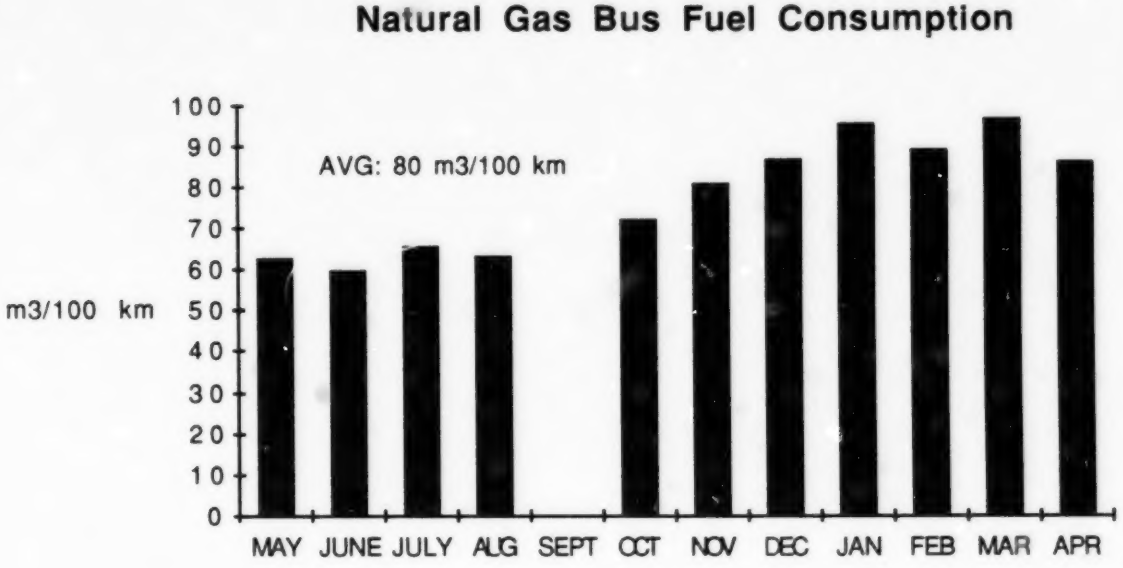
The natural gas refuelling station was built and owned by Union Gas. The compressor station was assembled in a factory on a skid pad and then shipped to the HSR garage site. The compressor had a capacity of 200 cfm (5.67 m^3/min) and was powered by a 200 hp electric motor. It was capable of fast-filling one bus in 15 minutes with the use of a buffer storage system. Without the buffer, the fill time was approximately 40 minutes. Normally, the buses are refuelled through a slow fill line.

Prior to beginning the demonstration, a natural gas and diesel bus were run on a simulated bus route to compare fuel economy and performance. Part of the route included a climb up the Niagara escarpment, because concern had been expressed with regard to the power output of the engines.

In the fuel economy test, the natural gas buses achieved 59.4 m^3/100 km while the diesel bus achieved 52.6 L/100 km. On an energy basis, the energy consumed by the natural gas bus is 9% greater than the diesel bus and is very close to the result obtained with propane. The performance of the natural gas bus was the same as the diesel; it climbed the escarpment at the same speed as the diesel [7].

The six buses were converted and operational by early 1987. Starting in May 1987, the total fuel consumed by the six natural gas buses was recorded on a monthly basis. The monthly variation in the average fuel consumption for the six buses is shown below. For the first four months, the fuel consumption was close to that predicted by the simulated bus route. However, as the winter months approached, the fuel consumption increased steadily. The reasons for the increase are not fully understood. Operation at non-optimal air-fuel ratios, excess idle time, and cold

weather operating conditions are contributing factors. For the year, the average fuel consumption was 80 m3/100 km. During the same period, the diesel buses averaged 69.5 L/100 km.

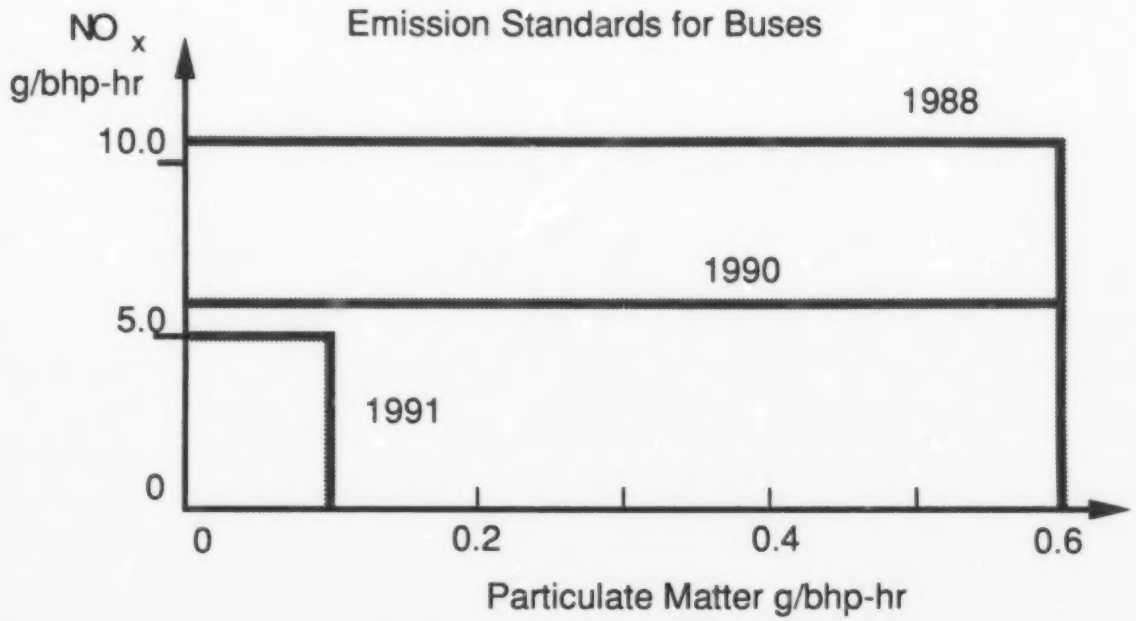


The first phase of this demonstration was completed on March 31, 1988. Fewer difficulties were experienced with this demonstration than the propane one because of the experience gained in Ottawa. Planning is under way to expand the demonstration fleet to ten buses and to acquire some original equipment manufactured (OEM) buses.

4.2/ Development of a Natural Gas Bus

In 1986, the U.S. Environmental Protection Agency passed new rules regulating the emissions of buses in the U.S. The rules would initially come into effect in 1988 and would progressively become more stringent until 1991. Stricter standards were also brought in for trucks, however the truck emission standards will not catch up to the bus standards until 1994. The standards for HC and CO were set at 1.3 and 15.5 g/bhp-hr respectively and do not change with time. However, the standards for NO_x and particulate matter were made increasingly stricter with time and they are shown below. As can be seen in the illustration below, the greatest reductions are to be achieved in particulate matter. Particulate matter is controlled because studies have indicated that they are carriers of carcinogens into the lungs.

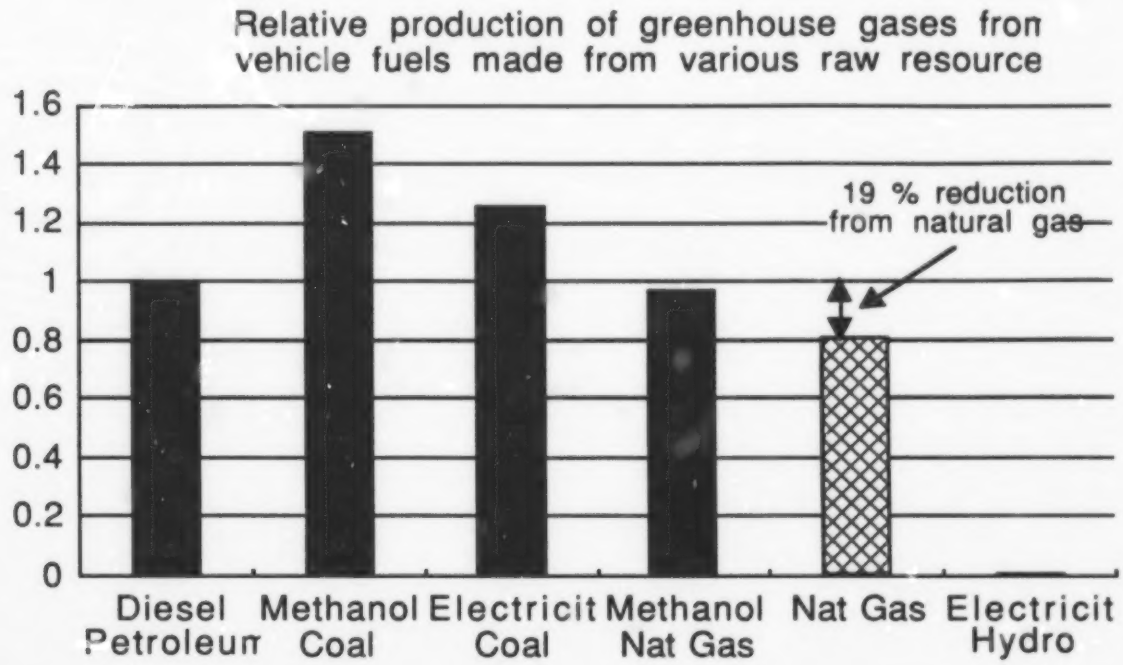
To meet these emission standards, governments and industry investigated two approaches. One approach was to use particulate traps and the other was to use alternative fuels. The approaches were different in that the trap would capture the particulate matter produced by the diesel fuel and then burn it off. On the other hand, it was known that the combustion of alternative fuels produced extremely low levels of particulates and that the standard could be met without a trap. To meet the standard with alternative fuels, it was thought that an automotive type catalyst would be required to meet the proposed standard for hydrocarbons, NO_x, and carbon monoxide.



While the Ministry of Transportation has programs in both trap technology and alternative fuels, the primary focus is on the use alternative fuels. The diesel engine manufacturers are developing particulate traps, but have not given any indication of when such systems will be ready for the market.

Recently, the global warming issue has been added to the list of environmental concerns. Global warming is related to the amount of carbon dioxide and other greenhouse gases present in the atmosphere. Of the greenhouse gases, carbon dioxide contributes 49% to the global warming affect, methane 18%, chlorofluorocarbons 14%, nitrous oxide 6%, and other gases 13%. Since carbon dioxide is the main contributor, methods are being sought to reduce its production. Two commonly proposed ways to reduce carbon dioxide emissions are conservation and utilization of fuels with a high hydrogen-to-carbon ratio. Methane, the primary constituent of natural gas, has the highest hydrogen-to-carbon ratio.

The question of the production of greenhouse gases from various fuels was studied in the paper, "Transportation Fuels and the Greenhouse Effect" [8]. The paper calculates, on an energy equivalent basis, the relative amount of carbon dioxide gases generated throughout the complete production and utilization cycle, by vehicle fuels made from a variety of raw feedstock energy sources, ie. electricity from coal, methanol from natural gas, and natural gas used directly. The results are given below. It shows that natural gas vehicles would reduce the production of greenhouse gases by 19% compared to diesel/gasoline powered vehicles.



Since MTO had been researching the use of alternative fuels in transit, the decision was taken to continue to pursue that line of research to try to meet the proposed emission standards. MTO reviewed its bus demonstration program in both propane and natural gas and, in late 1986, made the decision to pursue the development of a modern natural gas engine that could be used in transit buses. Some of the influencing factors that led to the selection of natural gas were fuel availability, cost savings, and its high octane rating. The Ministry of Transportation, the Ministry of Energy, Consumers Gas, Cummins, and Ortech International undertook a program to develop a natural gas version of the Cummins L10 diesel engine.

Before the development work on the L10 began, the emission characteristics of the Iveco natural gas engine were measured at Ortech [5]. It was found that the NO_x emission level was 58% higher than that of a 6V-71 diesel. Attempts to reduce the NO_x levels by operating the engine in the lean burn regime were investigated. While the NO_x level was reduced by using lean burn, the engine power level was also reduced. It was clear that either a larger engine or a turbo-charged engine would be required if the lean burn strategy was to be pursued. Since the Cummins L10 engine was turbo-charged, it was thought that the lean burn approach should be investigated to meet the NO_x emission levels. The initial engine development work was completed at Ortech and the engine was then shipped to Cummins for further work. Cummins has stated that the engine will meet the 1991 diesel engine standard with the use of an oxidation catalyst.

With the engine under development at Ortech, discussions were undertaken with Ontario Bus Industries (OBI) to install and evaluate the engine in a transit bus. OBI had previously installed a modified GM 7.4L engine in one of its Orion buses and had put the bus into operation in Mississauga. A second one would be converted and equipped with the L10.

In late 1987, the Toronto Transit Commission (TTC) approached the Ministry of Transportation for assistance in undertaking the evaluation and demonstration of alternative fuelled buses in its operations. The TTC wanted to undertake the demonstration because of the continuing need for efficient and environmentally acceptable transit and because of the implications of the proposed more stringent emission standards. On March 8, 1988, the TTC approved the demonstration of natural gas powered buses. The demonstration would comprise 25 buses and a fuelling station specifically designed to meet the fuelling demand.

In addition to the TTC, both Hamilton Street Railway and Mississauga Transit had expressed a desire to participate in the program to demonstrate OEM natural gas buses. To deliver these buses, MTO, TTC, Mississauga, and Hamilton entered into a technology development and demonstration program with Ontario Bus Industries (OBI). Cummins Engine Company agreed to supply the engines.

The program was divided into three phases. In the first phase, OBI modified two of its current 96-inch wide buses to accept roof-mounted tanks and the natural gas engine. These two vehicles are concept buses for the new production bus being proposed and use currently available natural gas storage cylinders and early versions of the natural gas engine. The buses and engines are providing early operational and durability information to the bus and engine suppliers and to the transit systems. In the second phase, the new prototype natural gas bus was designed and developed. It is 102

inches wide and is designed to incorporate four 6 m cylinders on the roof. Due to delays in certifying the new 6 m cylinders, the prototype bus was built with currently available cylinders. In the third phase, the buses will be manufactured and demonstrated. Current plans are to build 25 buses for TTC, 15 for Hamilton, and 10 for Mississauga.

The natural gas bus fuel system will incorporate two new features. The natural gas will be stored in four 6 m composite aluminum cylinders and they will be mounted on the roof. Each tank will contain 100 m^3 of gas stored at a pressure of 3000 psi (204 bar). The decision to mount the cylinders on the roof was chosen after consideration of some of the design requirements.

One of the requirements was vehicle range. The TTC preferred a vehicle with a range of 650 kilometres. Insufficient space was available under the bus to achieve this range with regular cylinders, which have a diameter of 355 mm. This led OBI to consider placing them on the roof. Since space and geometric limitations were not a constraint on the roof, consideration was given to using 6 m long cylinders. The selection of four 6 m cylinders rather than a larger number of shorter cylinders was made to minimize the number of connections and potential leak locations. To accommodate the extra weight on the roof, the upper structure of the bus was strengthened.

A further evaluation of the design led to the conclusion that the roof-mounted design had several additional advantages. In evaluating fuel systems, one consideration is that leaking fuel must be kept out of the passenger compartment. Since natural gas is lighter than air, any fuel leaking from the tank connections or piping would tend to rise. With the cylinders mounted on the roof, any leaking gas would readily escape from the ventilated canopy covering the tanks and rise away from the passenger compartment.

Another advantage of roof-mounted cylinders is that they are away from the impact area in the event of a collision. Also the tanks are protected from road hazards and the salt and spray environment typically found in Canadian and northern U.S. cities.

With the cylinders mounted on the roof, a slight degradation in the roll stability of the natural gas bus relative to a diesel bus is anticipated. This will be evaluated by placing the bus on a tilt table and comparing the angle at which the natural gas bus and a conventional bus begin to roll. At this time, there is no Canadian requirement for a minimum acceptable roll angle. To minimize the affect of the cylinders on the roll stability, changes will be made to the suspension system and the width of the bus will be increased to 102 inches.

The natural gas is stored in lightweight fibre-reinforced composite aluminum cylinders. The resin-impregnated fibreglass is wound under tension onto the low wall thickness cylinder liner. This process differs from previous designs where the fibreglass was put into tension by autofrettaging the cylinder liner. The cylinder is designed for a minimum burst pressure of 7500 psi (510 bar) and the design has been submitted for registration in Ontario.

One of the new features of this demonstration will be the installation of a fuelling facility that can supply the fuel flow rates required for a natural gas bus service line. To properly design this station, an operational study of the refuelling line was undertaken at a TTC bus garage. For each bus, the study recorded the volume of fuel loaded, refuelling time, elapsed time in the line, and the length of the queue [9]. As a result of the study, it was concluded that the compressor station should have a capacity of approximately 2200 cfm (62.4 m^3/min), which will be supplied by four 550 cfm (15.6 m^3/min) compressors. The contract for the station was awarded in February 1989 and is scheduled to be completed in one year.

Since the buses may be stored inside the garage, a study was initiated to determine the types of changes that may be required to permit them to be stored safely indoors. The principal purpose of the study was to assess the impact of natural gas leaks on the design of the facility. The study has three components. The first is to obtain both physical and operational data for each garage at each of the three demonstration sites. The second was to build a scale model of the storage area and bus to simulate and measure the effects of a range of leakage rates. The third was to perform a risk assessment of the potential hazards and to recommend changes to the facilities.

The study is currently under way and is focusing on two types of failures. In the first scenario, it is postulated that the bus has developed a low steady-state leakage rate of less than 10 cfm (.28 m^3/min). This leakage rate is representative of what might be expected from a loose pipe connection. The second type of failure being investigated represents the other extreme: a transient leak from the fuel line being completely severed and resulting in the complete venting of the cylinder. In the study, the air exchange rates and air circulation rates are being varied to assess how they affect the concentration and size of the natural gas vapour cloud. The results from this study will supply information to determine the types of modifications necessary to transit garages.

All of the components needed to proceed toward a full-scale demonstration of natural gas buses in 1991 are now under way. The prototype bus powered by a newly developed natural gas engine is being tested. A fuelling station capable of supplying natural gas at high flow rates is in the design phase and garage modification studies

are under way. With all of these components in place, it will be possible to evaluate the use of natural gas in transit on a large scale.

5/ CONCLUSIONS

In 1980, Ontario initiated a conservation and oil substitution program to reduce the consumption of oil. To achieve the objective, fiscal support was given to the private sector and a combination marketing and technology development program was initiated. The technology development program resulted in a series of development and demonstration projects in light- and heavy-duty vehicles. A large number of the programs were conducted cooperatively with the Canadian federal government, the Ontario provincial government, and the private sector.

These demonstrations showed that propane and natural gas can be used in transportation and promise significant environmental and economic advantages. To obtain the environmental benefits and to meet stricter emission standards, accurate fuel metering equipment and catalysts similar to those developed for gasoline will be required. However, economic and reliable operations with alternative transportation fuels will depend on the availability, cost, and reliability of vehicles supplied by original equipment manufacturers (OEM). Ontario initiated its natural gas bus development and demonstration program to advance the introductory date of OEM buses. All of the components needed to proceed toward a full-scale demonstration of natural gas buses in 1991 are now under way.

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